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CALCULATORS AND STRATEGIES FOR PROBLEM SOLVING IN GRADE SEVEN: AN IMPLEMENTATION PROGRAM AND STUDY

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REPORTS

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Sincerely,

Walter Szetela

Doug Super

CALCULATORS AND STRATEGIES FOR PROBLEM SOLVING IN GRADE SEVEN: AN IMPLEMENTATION PROGRAM AND STUDY*

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Introduction

This report describes a program which was aimed at the improvement of problem solving skills of grade seven students. The principal means for achieving the objectives were through the use of selected problem solving strategies along with supplemental use of calculators in one of the major treatment groups. Participating teachers and their classes were from the school districts of Richmond, Vancouver, and North Vancouver, British Columbia. This report presents the results and analyses of the implementation program which was conducted throughout the school year of 1980-81.

Rationale

The importance of problem solving in mathematics has long been recognized, but only recently has such recognition been prominently proclaimed. "Learning to solve problems is the principal reason for studying mathematics." (National Council of Supervisors of Mathematics, 1976). Even more recently, (1981), Recommendation 1 in a report of the National Council of Teachers of Mathematics, states that "Problem solving must be the focus of school mathematics in the 1980's." In general, problem solving has not been well taught in elementary schools, partly because the curriculum today is essentially a calculation curriculum, and there has been little time to teach problem solving. In addition to limitations of time, textbooks abound with problems in which the major obstacle is the determination of the correct operations to use. Such problems give little opportunity to utilize and practice a number of effective problem solving strategies which can greatly expand the problem solving ability

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In particular, these problem solving strategies include the following:

a) Guess and Test
b) List all Possibilities
c) Make a Table
d) Look for a Pattern
e) Draw a Diagram
f) Solve a Simpler Problem

These are strategies which were presumed to be teachable and learnable at the grade seven level. Such strategies also greatly enlarge and enrich the problem situations which grade seven students can encounter. Motivational aspects of the wide variety of more interesting contexts of many of these problems may also be of considerable value.

In connection with the difficulties which teachers experience in finding time to teach problem solving in the calculation curriculum, the easy availability of the hand-held calculator may provide a saving of time in performing calculations which may enable teachers to devote more thrust to problem solving. Time normally spent on tedious calculations can better be spent on thinking about how to solve the problem. Ideally, more time could be saved by reducing the amount of time spent on long pencil-and-paper computations in school mathematics. Unfortunately, schools remain resistant to suggestions to reduce certain lengthy calculations even though such pencil-and-paper calculations are rarely practiced in the everyday world. This resistance continues despite growing support and evidence in favor of calculators as reported in the state-of-the-art review of studies of calculators in education by Suydam (1960). More specifically, previous studies by Szetela (1979,1980,1982), have indicated that when calculators were used, significant improvement in story problem achievement results. One criticism of calculator studies is that they tend to be short term. Thus, claims that use of calculators does not reduce paper-and-pencil computational skills are considered to be invalid. The length of the present program and study covering a full school year not only provides

an opportunity to observe effects of calculator use over a significantly lengthy period of time, but also provides teachers with time needed to provide sufficient problem solving experiences for their students in a curriculum that is heavily laden with pencil-and-paper computational objectives.

Objectives

The general objectives of this program were to demonstrate that a problem solving program could be implemented in schools within the existing structure of today's curriculum, and to determine the effects of such implementation. In particular, the following questions were addressed:

1. In the present curriculum and classroom structure, will teachers be able to carry out a program of problem solving which utilizes problem solving strategies not generally taught in grade seven classrooms?
2. Will students who are taught problem solving strategies perform better on problem solving tests than students who receive no special additional problem solving instruction?
3. Will students who are provided with calculators in addition to problem solving instruction perform better on problem solving tests than students who do not use calculators?
4. Will students who use calculators throughout the year maintain their paper-and-pencil computational skills in comparison with groups not using calculators?
5. Will the problem solving performance of boys and girls be similar?
6. Will any differences in problem solving performance depend upon the nature of the problem solving test. More specifically, will tests on more traditional text book type problems produce results that are different from tests with focus on more diverse problem solving strategies and tests requiring more extensive analysis, planning, and execution?
7. Will students who are taught problem solving strategies with or without calculators have a higher attitude toward problem solving than students who receive no special instruction on problem solving?

Subjects

Subjects for the program and study were the students in the classes of teachers in Richmond, Vancouver, and North Vancouver who volunteered to follow a problem solving program and additional teachers, primarily in Richmond, who volunteered to take all tests and who would act as a control group. Thus, there were three groups. One group of teachers used problem solving strategies supplemented by calculators (CP), a second group used problem solving strategies only (P), and the third group insructed their classes with no externally provided programs or materials, acting as the control group (C). The number of teachers in the study initially within each treatment group is shown in Table 1.

District	Calculators and Problem Solving	Problem Solving Only	Control	
Richmond	14	11	22	47
Vancouver	5	5	3	13
North Vancouver	4	4	0	8
Totals	23	20	25	68

Table 1

Of greater relevance is the number of teachers who remained to give the mid year tests at the designated time. In addition, because the large majority of teachers were from Richmond, and because Richmond also had a large control group, there were two separate analyses of results. One set of analyses pertained to the Richmond District only. The other set of analyses were performed on the entire group of classes in all three districts. Table 2 shows the number of classes and number of students who took the mid year tests for Richmond and for all three districts.

Analysis Group	Calculators and Problem Solving		Problem Solving Only		Control	
	Classes	Pupils	Classes	Pupils	Classes	Pupils
Richmond	14	290	10	195	18	338
All 3 Districts	23	560	19	408	21	419

Table 2

Procedure

Because the problem solving strategies to be employed in this project were not generally well known to teachers, it was necessary to provide assistance and instruction to teachers in full day and half day workshops with participating teachers. Additional assistance was provided in meetings after normal school hours. In these sessions teachers were made aware of the objectives of the study,and they were given intensive experiences and activities utilizing problem solving strategies which they would be teaching. In addition, for teachers in calculator groups, additional instruction was provided on use of calculators for problem solving. Teachers were also presented with materials which would be used in the project. These materials included a wide variety of commercially available materials such as problem solving decks and booklets. The materials which were used most extensively were the problem solving deck, Techniques of Problem Solving (TOPS) by Imerzeel et al, the calculator problem solving deck, Project IMPACT by Ockenga, et al, and the problem solving booklets emphasizing particular strategies by Houghton-Mifflin Publishers. Other materials included The Workbox, a problem solving deck for calculators by J.C. Norman Sharp of Addison-Wesley, Calculator Explorations and Problems by Don Miller of Cuisenaire Publications, and Keystrokes: Exploring New Topics by Reys et al for Creative Publications. Calculators were provided by participating school districts at a ratio of one calculator per two students in the calculator classes.

Richmond teachers volunteered to assist with the planning of the program to correlate the problem solving materials with the classroom textbooks. Teachers were provided with suggested problems to be used in conjunction with the topics in their textbooks and in the British Columbia Curriculum Guide. The first set of problems covered the work of the first month, and thereafter teachers were provided with suggested problems correlated with the texts for periods of at least two months. Two textbooks were mainly used in the classrooms, and the problems were correlated with each text. The order of suggested problems differed because of the

different sequential arrangement in the two textbooks, but the totality of problems was the same in the two main treatment groups. Teachers in the Control groups were not given any additional materials.

Two graduate students visited each teacher not in the Control groups to obtain feedback from teachers relative to any problems or questions which might arise. In addition, at the request of several teachers, demonstration lessons on problem solving were given.

To obtain the data necessary to measure the effects of the implementation program, tests were administered at the beginning of the year, in February, and in June. The pretest in September was followed by two problem solving tests in February, and several more tests in June including a test of attitude toward problem solving.

Liaison with the teachers in the three districts was provided by Mr. Norman Duncan, Elementary Coordinator in Vancouver, by Mr. James Bourdon, Supervisor of Elementary Instruction in North Vancouver, and directly by Doug Super, Mathematics Coordinator in Richmond. These liaison persons were vital to the transmission of instructions and materials to participating teachers as well as arranging and expediting release time for teachers for the necessary in-service preparation.

Test Instruments

The following list describes the type, source or construction, and purpose of each test administered in the project:

1. Pretest, September. This was a 40-item test on whole number skills and concepts, part of a battery of tests prepared for British Columbia schools by Robitaille, Sherrill, Klassen, and Kelleher. This test was given at the outset of the study to determine if there were significant differences among the treatment groups prior to the treatment.
2. Traditional Problem Solving Test, February. This was a test containing 20 problems of the type usually found in school textbooks. The main obstacle in problem solving here is selection of the correct operations to be used. This

test was constructed by the program planners to correlate as closely as possible to the topics of instruction which had been taught up to this time.

3. Strategies Problem Solving Test, February. This test was given within two days of the previous test. This test also contained 20 problems, but strategies such as Guess and Test, Draw a Diagram, or Look for a Pattern would more likely characterize a solution than merely selecting the correct operations. This test was also constructed by the program planners. An initial version of both February tests was piloted by several Richmond teachers who did not participate in the study.
4. Attitude Toward Problem Solving Test, May. This is a 36-item scale designed by Donald R. Whittaker of Ball State University, Muncie, Indiana. The test uses a 5-point Likert scale and is easily administered.
5. Rational Numbers Test, June. This is a second 40-item test on rational numbers in the battery of tests by Robitaille, Sherrill, Klassen, and Kelleher. The purpose of this test which was worked using only pencil and paper by all students, was to determine if students who had used calculators in problem solving throughout the year maintained their paper-and-pencil computational skills as well as those who had not used calculators throughout the year.
6. Traditional Problem Solving Test, June. This test of 20 problems was similar to one of the February tests. Again the problems were of the type to be commonly found in text books. The problems covered new content such as decimals and percent problems as well as review content. Various versions of this test were piloted by teachers in Richmond and in Vernon, British Columbia. This test was given to approximately half of the students in each participating class. Different tests were given to the remaining students.

7. Strategies Problem Solving Test, June. Again this test was similar to one of the February tests. It contained 20 problems whose solution usually required some use of a strategy beyond choosing the correct operations. The test constructed by the program planners, was piloted in Richmond and Vernon. The test was given to approximately half of the students in each participating class.
8. Sustained Problem Solving Test, June. This test contained only 4 problems, each of which required an ability to go well beyond a simple translation of the problem followed by a brief application of a problem solving strategy. In addition to a thorough comprehension of the problem, it was necessary to make extensive lists or to apply a well coordinated guess and test procedure. Unlike all previous tests, the problems would receive part credit, and it was necessary to score these tests carefully according to scoring guidelines which would allow a range of zero to 5 points for each problem. In the totality of students in the study every 15th student was scheduled to take this test.

It will be noted that the last three tests listed were given at a single sitting in each class. This procedure was chosen because it would minimize loss of time by teachers for purposes of test administration, and it would maximize the information desired for the study. Although only about half of each class would contribute to a class mean for the final traditional problems test as well as the strategies problems test, it was felt that the smaller numbers would still be sufficient to provide meaningful data. In addition the approximately 70 papers from the Sustained Problem Solving Test would provide a reasonably adequate sample for analysis of non-routine problem solving performance.

Data Anaysis

There were two separate sets of analyses, one for the Richmond District, and the other including all three participating districts. The Richmond groups comprised the substantial majority of participating classes, especially classes in the control group. There were no classes in the control group for North Vancouver. For that reason, although data were analyzed for all three treatment groups in total for the three districts, any results reported involving the control group in the three district analyses are given for reasons of curiosity rather than significance. However, a case for more credence to any significant results related to the control group might be made on the basis that the pretest results indicated no significant differences between districts and treatment groups.

Although problem solving tests at midyear and at year's end were similar, they were not identical in content. Therefore it was deemed to be inappropriate to use a repeated measures method of analysis. Multi-variate analysis was not chosen because tests were given at several different times. It was decided to use separate fully nested analyses of variance for each of the dependent variableswith treatment by classes nested within treatment except for analyses of sex differences and for the sustained problem solving test differences. Because the cells for subjects in the sex difference analyses would be very small on two major final problem solving tests, the analysis by sex was a fully crossed , treatment by sex design. For the sustained problem solving test where no more than two subjects were from any one class, the subjects were considered to be randomly assigned, and a univariate analysis of variance was made.

The number of classes declined during the study for several reasons. Some teachers in the control group who administered the pretest either declined to give the midyear tests or else gave the tests beyond an established two week testing period. This resulted in a loss of 4 teachers. One additional teacher was lost because of serious illness. In May 4 more teachers either failed to give the test on rational numbers or the results were lost in

the school mailing. For the final three problem solving tests results from 8 more teachers were either missing or unusable. The unusable results from 3 teachers were due to the fact that the teachers returned only the answer sheets from which it could not be determined which test was taken. The answer sheets for two of the tests were identical, and it was necessary to match each test returned with the answer sheet. The remaining 5 teachers either failed to give the final tests or the tests were lost in the school mail. The attrition resulted in a total of 36 classes in Richmond and 54 in the total of three districts at the end of the year. Pretests in September had been given to 47 classes in Richmond and 68 in the total of three districts. The attrition of teachers was distributed with 7 teachers from the control group, 4 from the problem solving group, and 3 from the calculator and problem solving group.

Results

For each test the results will be presented in a table to be followed by brief comments. Table 3 shows the results of the pretest.

PRETEST RESULTS FOR RICHMOND AND COMBINED DISTRICTS

	Richmond			Combined Districts		
	Classes	Students	Mean	Classes	Students	Mean
Calculators and Problem Solving	14	290	26.38	23	560	26.34
Problem Solving	10	195	25.23	19	408	26.27
Control	18	338	25.87	21	419	26.19

Table 3

The results show quite clearly that there were no significant differences among the treatment groups at the outset of the study.

The results of the two problem solving tests at midyear are given for the Richmond groups in Table 4. Each test contained 20 problems.

MIDYEAR TEST RESULTS FOR RICHMOND

	Traditional Problems			Strategy Problems		
Treatment Group	Classes	Mean	SD	Classes	Mean	SD
Calculators and Problem Solving	14	13.51	4.17	14	10.37	4.18
Problem Solving	10	13.70	4.13	10	10.86	3.89
Control	18	12.13	4.43	18	9.30	3.92

Table 4

The analysis of variance indicated that the Problem Solving (P) group was significantly higher than the Control (C) group on both the traditional and strategies problem solving tests. It is clear from the table that all students found the strategies test more difficult than the traditional test.

The results of the two problem solving tests at midyear for the combined three districts are given in Table 5.

MIDYEAR TESTS FOR COMBINED DISTRICTS

	TRaditional Problems			Strategy Problems		
Treatment Group	Classes	Mean	SD	Classes	Mean	SD
Calculators and Problem Solving	23	13.94	3.95	23	10.80	4.04
Problem Solving	19	14.27	4.07	19	11.64	3.81
Control	21	12.20	4.51	21	9.26	3.89

Table 5

There are no differences between the calculator and problem solving (CP) group and the (P) group. Both the CP and P groups are significantly higher than the C group. The latter observation is tempered severely by the absence of control classes in North Vancouver although that district comprised only 8 of the 63 classes in the study.

The results of the test on rational numbers given late in the year are shown for both Richmond and the combined districts in Table 6. For this test of 40 items all students used pencil and paper only.

RATIONAL NUMBERS TEST RESULTS FOR RICHMOND AND COMBINED DISTRICTS

	Richmond			Combined Districts		
Treatment Group	Classes	Mean	SD	Classes	Mean	SD
Calculators and Problem Solving	13	28.80	7.93	22	28.82	8.10
Problem Solving	9	28.68	7.69	17	29.16	7.84
Control	17	27.10	8.71	20	27.45	8.81

Table 6

There are no significant differences among treatment groups on the rational numbers test. It is apparent that use of calculators on problem solving throughout the year has not reduced the paper-and-pencil computational skills of students.

The results of the traditional problem solving test and the strategies problem solving test at the end of the year are given for Richmond in Table 7. Each test contained 20 problems.

YEAR END TEST RESULTS FOR TWO PROBLEM SOLVING TESTS(RICHMOND)

	Traditional Problems			Strategy Problems		
Treatment Group	Classes	Mean	SD	Classes	Mean	SD
Calculators and Problem Solving	12	11.83	4.15	12	9.96	4.04
Problem Solving	9	10.74	3.17	9	9.12	4.01
Control	15	9.98	4.28	15	8.00	4.13

Table 7

The statistical analysis indicated that the CP group scored significantly higher than the C group on both the traditional and the strategies problem solving tests. Again it is clear that all groups found the strategies test more difficult than the traditional test.

For all three districts combined the results of the traditional and the problems solving strategies tests at the end of the year are given in Table 8.

YEAR END RESULTS FOR TWO PROBLEM SOLVING TESTS(COMBINED DISTRICTS)

	Traditional Problems			Strategy Problems		
Treatment Group	Classes	Mean	SD	Classes	Mean	SD
Calculators and Problem Solving	20	11.80	3.98	20	9.61	3.95
Problem Solving	16	10.95	3.53	16	9.48	4.36
Control	18	10.27	4.22	18	7.98	4.04

Table 8

The statistical analysis indicated that the CP group scored significantly higher than the C group on both the traditional and strategies problem solving tests. This result coincides with the results for Richmond district only.

The test on sustained problem solving consisted of 4 problems. Each problem had a maximum value of 5 points. Scoring of this test was difficult because of the subjective nature of evaluating work done by students. The criteria for scoring the test included certain arbitrary agreements among the three persons who scored the tests. For example a score of 4 was given if the answer was correct but no work was shown. (The directions did state that work must be shown.) The persons who evaluated these tests were one of the investigators, one of the participating teachers, and a graduate student. Each test was scored independently, results were compared, and tests were rescored again when anomalies in some scores were noticed. These occasional anomalies were usually due to certain obscurely written calculations which were sometimes very significant yet easily overlooked in a mass of scribbles. The present results represent the mean scores obtained by the three evaluators. This evaluation problem will continue to be addressed in order to try to develop criteria for scoring which will ensure high reliability.

There was a total of 68 of these tests from students who had been in the project all year. Four papers from students who had joined their classes later in the year were omitted from analysis. Table 9 shows the results of this test for Richmond and for all three districts combined.

YEAR END RESULTS OF SUSTAINED PROBLEM SOLVING TEST

	Richmond		Combined Districts	
Treatment Group	N	Mean	N	Mean
Calculators and Problem Solving	15	8.64	27	8.95
Problem Solving	8	11.50	21	10.03
Control	14	8.25	20	7.56

Table 9

The results indicate that the P group performed better on the sustained problem solving test than the other two groups.

The results of the 36-item scale of attitude toward problem solving are given in Table 10 for Richmond and for the combined districts.

ATTITUDE TOWARD PROBLEM SOLVING RESULTS(RICHMOND AND COMBINED DISTRICTS)

	Richmond			Combined Districts		
Treatment Group	Classes	Mean	SD	Classes	Mean	SD
Calculators and Problem Solving	12	123.98	21.75	21	122.82	20.74
Problem Solving	9	115.58	20.87	17	119.52	18.94
Control	17	117.25	19.04	20	118.16	18.42

Table 10

For the Richmond district the CP group had a significantly higher attitude than the other 2 groups. That this difference was marginal is indicated by the fact that none of the differences were significant when all districts were compared.

Sex Differences

The results of the analysis of sex data are considerable, and most of the results are non-significant. A few differences did occur in favor of the boys. However, such differences were quite small, and even they must be regarded as questionable differences because the unit of analysis was the individual rather than the intact class. If the class had been used as the unit of analysis, the cell sizes for two of the end of the year tests would have been quite small because each test was given to only about half of each class. Rather than report the entire battery of results, only the results for the total of boys and girls are given here for each test for both Richmond and for all 3 districts.

RESULTS FOR ALL TESTS ON SEX DIFFERENCES(RICHMOND AND COMBINED)

	RICHMOND				COMBINED DISTRICTS			
Test	Group	N	Mean	SD	Group	N	Mean	SD
Pretest	Boys	393	25.71	6.49	Boys	687	26.01	6.49
	Girls	395	26.15	6.32	Girls	663	26.47	6.14
Midyear Traditional Problems	Boys	393	13.15	4.34	Boys	687	13.78	4.29
	Girls	395	12.70	4.31	Girls	663	13.19	4.19
Midyear Strategies Problems	Boys	393	9.97	4.18	Boys	687	10.59	4.25
	Girls	395	9.98	3.95	Girls	663	10.52	3.82
Rational Numbers	Boys	318	27.74	8.37	Boys	579	28.24	8.58
	Girls	322	28.01	8.21	Girls	555	28.58	7.98
End year Traditional Problems	Boys	151	10.67	4.13	Boys	269	11.21	4.04
	Girls	145	10.89	3.94	Girls	247	10.86	3.84
End year Strategies Problems	Boys	139	9.36	4.26	Boys	248	9.46	4.21
	Girls	139	8.47	3.99	Girls	238	8.64	4.07
Attitude	Boys	325	120.12	19.65	Boys	572	121.19	18.79
	Girls	327	118.25	21.36	Girls	546	119.69	20.14

Summary

This study and implementation program demonstrated that a program of instruction in grade seven which incorporated problem solving strategies, supplementary printed materials, and calculators was indeed feasible for teachers within the present curriculum structure. Every teacher in the two treatment groups given a program to follow, stayed with the program throughout the year except for two teachers, one of whom left because of illness, and one of whom did not give the final tests. The program was enthusiastically received by the overwhelming majority of teachers.

The effectiveness of the program was encouraging although differences were not as great as hoped. In every comparison between the two main treatment groups and a control group, at least one of the groups following a problem solving program performed significantly better than the control group, when the comparison involved problem solving achievement or attitude toward problem solving. On the rational numbers test which was given to determine if students using calculators throughout the year would suffer a loss of paper-and-pencil computational skills, the non-significant results indicate that even over a year long period, calculators can be used advantageously without risk of such skills. The results for Richmond district and all three districts were very consistent. It is interesting that on the midyear tests the Problem Solving (P) group performed better than the Control (C) group in Richmond, but on two similar tests at the end of the year, the CP group performed better than the C group. The CP group also had a higher attitude toward problem solving than either of the other two groups in Richmond.

It is also of interest that on a test of sustained problem solving at the end of the year, the P group excelled over the other two groups. In no case did a C group perform better than either of the two groups following a problem solving program. While differences were not large, the uniformity of results in favor of the problem solving groups with or without calculators is most encouraging. Problem solving skills almost certainly must be developed over long periods of time. One full year is a good

start. One can certainly be optimistic about a problem solving program which begins much earlier than in grade seven.

In this study there were only very small differences between boys and girls. The results indicate that at grade seven level boys and girls differ very little if at all in problem solving ability.

Implications of theStudy

The encouraging results of this implementation program and study should serve to support school districts who recognize the need to improve problem solving skills at the elementary school level. At the same time the performance of students who used calculators along with problem solving strategies indicates that schools should be less hesitant to more widely incorporate calculators in their mathematics learning activities. The fact that a substantial number of teachers found that they could carry out their regular teaching plans and in addition use a wide variety of problem solving materials indicates that even in a curriculum which is largely calculational, problem solving instruction can be given much greater attention.

The success of this implementation program at the grade seven level naturally leads to the question about applying such a program in earlier grades. The planners of the grade seven program are enthusiastic about following that course. We think that every school district should move rapidly in the direction as recommended by the National Council of Teachers of Mathematics. "Problem solving must be the focus of school mathematics in the 1980's."

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